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Chaos in a simple deterministic system

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2. We present a simple experiment, due to the late Pierre Bergé, showing that non-linear dynamic systems depending on a very limited number (minimum 3) of variables can behave in a chaotic manner.

   In this experiment, we use a damped oscillator, which can be solicited at variable amounts by an external frequency. As a reminder, an oscillator is a two-variables system (position and speed of the oscillating part) and adding an external periodic forcing adds another (third) variable.

   The oscillator is constituted by a rotator with two small magnets fixed to its two arms. These two magnets may move in the field created by two additional similar magnets fixed to the vibrating arm of a metronome. If the metronome is at rest, the oscillator moves in the static magnetic field, whose direction is determined by the position of the arm of the metronome. The system has two variables and only damped oscillations are observed.

   When the metronome is put into motion, a third variable is introduced. The oscillator now oscillates in a periodically varying magnetic field, with a coupling increasing when the two sets of magnets are progressively approached. The movement of the oscillator then changes from an initial periodic one to a new chaotic regime, which reverts back to periodic if the distance of the two sets of magnets is increased again. When the coupling is increased, the oscillator follows the well known period-doubling route to chaos.

   This experiment shows that a simple system, in which no place is left to hazard, may, nevertheless, behave in a very chaotic, unpredictable way.